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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : F17C 9/02

A1

(11) International Publication Number: WO 94/17325

(43) International Publication Date: 4 August 1994 (04.08.94)

(21) International Application Number: PCT/NO94/00020

(22) International Filing Date: 25 January 1994 (25.01.94)

(30) Priority Data:
930317 29 January 1993 (29.01.93) NO

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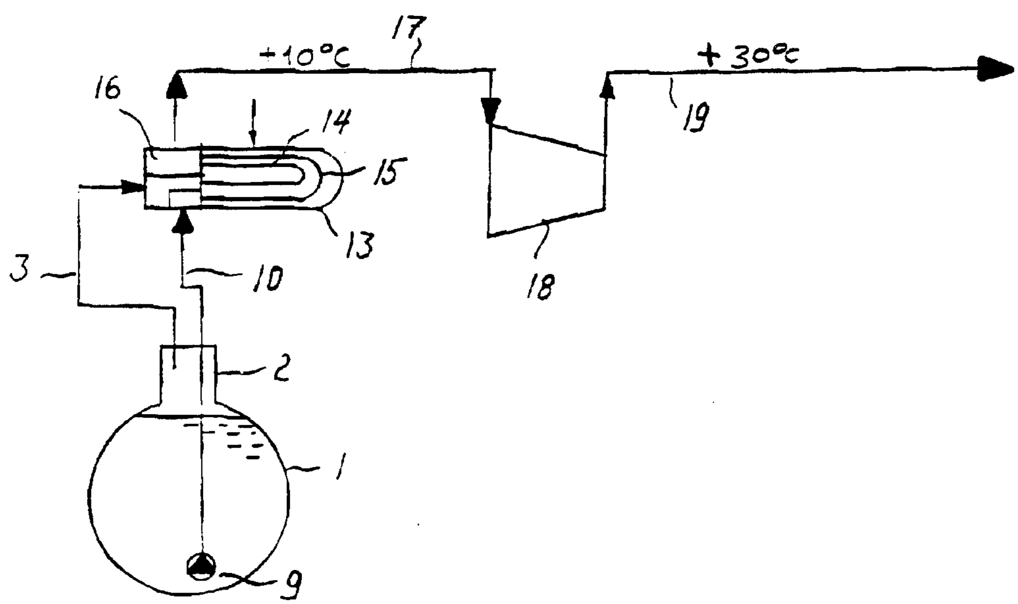
(81) Designated States: AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, KZ, LK, LU, LV, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: PROCESS AND SYSTEM FOR, RESPECTIVELY, THE UTILIZATION AND PROVISION OF FUEL GAS



(57) Abstract

In a system for the provision of fuel gas from decoction (boil-off) from liquefied petroleum gas and optionally gas produced by the evaporation of the liquefied gas, there is used a combined heat exchanger (13), wherein boil-off and liquefied petroleum gas are heated. Via a common mixing chamber (16) in the combined heat exchanger a combined stream of overheated gas may be supplied to a compressor (18). The compressor (18) may advantageously be of a normal type since its suction temperature will be sufficiently high to allow this, precisely as a result of the heating and evaporation, respectively, in the combined heat exchanger.

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PROCESS AND SYSTEM FOR, RESPECTIVELY, THE UTILIZATION AND PROVISION OF FUEL GAS.

The invention relates to a process for the utilization of boil-off (decoction) from liquefied petroleum gas as fuel gas in combination with gas produced by evaporation of the liquefied petroleum gas, where the boil-off and evaporated gas are brought together and compressed.

The invention also relates to a system for carrying out the method, wherein boil-off and evaporated gas are brought together and compressed, comprising a storage tank for liquefied petroleum gas, an outlet line for decoction from the storage tank, an outlet line for liquefied gas from the storage tank, an evaporator in the outlet line for liquefied gas, a flowline (header) connected to the two outlet lines, a compressor connected to the flowline, and a pressure pipe from the compressor.

As the technical background for the invention, the point of departure is the situation currently found aboard LNG ships, i.e., ships designed to carry liquefied natural gas. Ships carrying liquefied natural gas (LNG ships) at atmospheric pressure normally are not equipped with recondensation systems. Therefore, the gas which boils off as a result of leakage of heat into the tanks, here defined as decoction (boil-off), is used as fuel gas in the ship's steam boiler. The temperature of the cargo at atmospheric pressure will be about minus 160^{o}C for most LNG mixtures, while the gas temperature and pressure requirements at the inlet to the boiler burners are, respectively, plus 30^{o}C and minimum 0.5 bar g. When under certain operating conditions the boil-off is not sufficient to meet the total requirement for the boiler, the gas amount may be increased by evaporating LNG, here defined as gas produced by the evaporation of the liquefied gas, which is taken directly from the tanks.

In a common arrangement today for the utilization of boil-off and gas produced by evaporation of the liquefied petroleum gas, a compressor maintains the desired tank pressure by evacuating boil-off. The boil-off will receive some heat in the tank dome and the pipe system, causing the temperature at the inlet to a separator placed in front of the compressor to be increased from minus 160^{o}C to about minus 120^{o}C.

The pressure increase in the compressor causes a temperature rise of about 30^{o}C. To enable the supplying of the gas to the machine room with a temperature of about plus 30^{o}C, a heat exchanger (heater) is installed after the compressor for further heating of the gas.

If it is necessary to increase the amount of gas supplied to the boilers, a pump suitable for this purpose is started in one of the tanks, and LNG at minus 160^{o}C is sent on to an evaporator. Here the gas is evaporated and overheated to about minus 60^{o}C, prior to entering said separator and mixing with the boil-off. The separator is considered necessary because LNG taken from the bottom of the tanks contains small amounts of heavier hydrocarbons which have a droplet form after the evaporation, or conceivably can condense in the inlet to the compressor and damage it. When boil-off is used alone, the separator <u>per se</u> is not necessary, nor is it necessary if the temperature is sufficiently high in front of the compressor, eliminating the danger of precipitation of liquid drops.

It should be possible for the system to be run either with boil-off alone or with evaporation of LNG. The amounts will vary from 0 to 100% for both sources. If, for example, maximum gas consumption for the boilers is 5000 kg/hour and the boil-off amount is 4000 kg/hour, then 1000 kg/hour must be supplied via the evaporator. If the boil-off amount is 2000 kg/hour, then 3000 kg/hour must be supplied via the evaporator, etc. Thus, the suction temperature for the

compressor could vary between the extremes of minus 60°C and minus 120°C.

An existing system of this type involves an arrangement requiring four main components, namely: an evaporator, separator, compressor and heater. The operating temperatures are such that these components must be classified as cryogenic equipment, with special requirements with regard to materials and construction. This also applies to the pipework and instrumentation.

The purpose of the present invention is to simplify the process and the system.

According to the invention, therefore, we propose a process as described in the introduction above, characterized in that the boil-off and liquefied gas prior to the compression are overheated and evaporated, respectively, in their separate sections in a combined heat exchanger and are brought together in a common mixing chamber.

With regard to the new system, it is proposed according to the invention that the aforementioned system be designed such that the evaporator is constructed as a combined heat exchanger having two separate throughflow tube bundles disposed in a common surrounding shell, one said bundle being connected to the outlet line for liquefied gas for the evaporation thereof, and the other tube bundle being connected to the outlet line for boil-off for the overheating thereof, which tubes flow into a common mixing chamber which is connected to the flowline.

By means of the invention, the process and the system are radically simplified. Because the suction temperature of the compressor is raised substantially, the separator may be omitted, and the compressor need not be cryogenic, with the special requirements for materials, construction and design

associated therewith. Insulation of the pipelines may be omitted, and ice formation on the valves and expansion members is avoided. This simplification results in reduction of the amount of required space and a less complicated pipework system. The combined heat exchanger can be supplied at a price which is not substantially higher than that of each of the heat exchangers (evaporator and heater) in use today. The overall capital costs and operating expenses (including maintenance) over the lifetime of the ship will be reduced substantially.

Thermal engineering calculations indicate that it is possible to construct the combined heat exchanger with dimensions covering all conditions from 0-100% boil-off and from 0-100% evaporation. Furthermore, the apparatus may be regulated such that the gas exiting the heat exchanger maintains a temperature of plus 10^{o}C, so that further heating of 20-30^{o}C in the compressor will ensure that the gas supplied to the boilers has the correct temperature (and pressure).

The invention will now be explained in more detail, with reference to the drawings, where:

Fig. 1	is a purely schematic view of a known system,
Fig. 2	shows a system according to the invention, and
Fig. 3	shows the new combined heat exchanger with associated control system.

In Figure 1, numeral 1 designates a storage tank for liquefied petroleum gas, for example a tank for LNG aboard an LNG ship. As a result of heat penetration from the surroundings, so-called boil-off (decoction) will occur. This boil-off collects in the dome 2 of the storage tank and may be removed through an outlet line 3. This outlet line 3 runs to a separator 4, from which runs a line 5 to a compressor 6. In compressor 6 the boil-off is compressed, with an attendant increasing of the temperature. Further temperature increases

take place in a heater 7, from which runs a line 8 carrying fuel gas.

Tank 1 contains liquefied natural gas having a temperature of around minus 160^{O}. The boil-off, which is removed through line 3, will as a result of the supply of heat in dome 2 and in line 3 have a temperature of around minus 120^{O}C at separator 4. In compressor 6 the temperature increases to about minus 90^{O}C, and in heater 7 the temperature is increased to plus 40^{O}C.

The system is designed in such a way that if the decoction is insufficient, i.e., if greater amounts of fuel gas are needed than the boil-off can supply, then liquefied natural gas is extracted by means of a pump 9. From this submerged pump runs outlet line 10 for liquefied gas, on to an evaporator 11. From evaporator 11 runs a line 12 to separator 4. When the evaporated gas arrives at the separator it will have a temperature of about minus 60^{O}C.

The separator is considered necessary because the liquefied gas removed from the bottom of tank 1 after the evaporation contains small amounts of liquid drops. These can conceivably condense in the inlet of compressor 6 and damage it. For boil-off alone the separator is not necessary, nor is it necessary if the temperature is sufficiently high prior to the compressor to ensure that there is no danger of precipitation of liquid drops.

It is apparent from Figure 1 and the typical temperatures indicated therein that the operating conditions are such as to require that the components -- primarily the evaporator 11, separator 4, compressor 6 and heater 7 -- must be classified as cryogenic equipment, with special requirements as regards materials and construction. This applies also to the pipework and instrumentation.

A schematic view of the system according to the invention is shown in Figure 2. The system is intended to be connected to a storage tank 1 with a dome 2 and submerged pump 9 and an outlet line 3 for boil-off, as well as an outlet line 10 for liquefied petroleum gas, as in the system in Figure 1.

The two outlet lines 3 and 10 are led to a combined heat exchanger 13. This has two separate tube bundles 14 and 15 in the same shell, namely a bundle 15 for the evaporation of the liquefied gas and a bundle 14 for the overheating of boil-off. Both tube bundles flow into a common mixing chamber 16. From there runs a line 17 to a compressor 18. From compressor 18 runs a fuel gas line 19.

The combined heat exchanger may be regulated such that the mixed gas in line 17 will have a temperature of plus $10^{O}C$. As a consequence hereof, the fuel gas supplied by compressor 18 will have a temperature of around $30^{O}C$. The compressor in Figure 2 may be of a normal type since the suction temperature, as mentioned above, will be high (plus $10^{O}C$ instead of minus $120^{O}C$ as in Figure 1).

Volume control is effected in the system in Figure 1 by means of a control valve at the inlet of evaporator 11 and by regulation of the suction volume of compressor 6.

In Figure 2 one can employ a volume control of the compressor as in Figure 1. Regulation of the combined heat exchanger 13 in Figure 2 can be carried out as exemplified in Figure 3.

In Figure 3 we again see the combined heat exchanger 13 with the two separate tube bundles 14 and 15, and the two outlet lines 3 and 10. In addition, we find flowline 17, which runs to the compressor, not shown in Figure 3.

A line 20 branches off from line 10 to the mixing chamber 16 of the combined heat exchanger.

Quadrangle 21 represents a temperature control. Quadrangle 22 represents a flow control. The flow control directs a control valve 23 in the boil-off line 3 as well as a control valve 24 in line 10. Both of these control loops will in practice be integrated in a common data processor which also handles the other control functions in the system.

Temperature control out from the combined heat exchanger is carried out here by means of injection of liquefied petroleum gas through line 20 in mixing chamber 16 when the heat exchanger is working with both overheating of boil-off and the evaporation of liquefied gas. In heating of boil-off only, the temperature is controlled by means of pressure adjustment of the supply of vapour through line 25. Condensate is eliminated through line 26.

The invention is not limited to LNG as gas. Other liquefied gases, the boil-off of which is suitable for fuel/power fuel gas, could of course derive benefit from the invention.

P a t e n t   C l a i m s

1.

A process for the utilization of decoction (boil-off) from liquefied petroleum gas as fuel gas in combination with gas produced by evaporation of the liquefied gas, where boil-off and evaporated gas are brought together and compressed, c h a r a c t e r i z e d i n that the boil-off and the liquefied gas prior to the compression are overheated and evaporated, respectively, in their separate sections of a combined heat exchanger and are brought together in a common mixing chamber.

2.

A system for carrying out the process according to claim 1, where boil-off and evaporated gas are brought together and compressed, comprising
a storage tank (1) for liquefied petroleum gas,
an outlet line (3) for boil-off from the storage tank,
an outlet line (10) for liquefied petroleum gas from the storage tank (1),
an evaporator (13) in the outlet line (10) for liquefied gas,
a flowline (17) connected to the two outlet lines (3, 10),
a compressor (18) connected to the flowline, and
a pressure line (19) from the compressor,
c h a r a c t e r i z e d i n that the evaporator (13) is designed as a combined heat exchanger (13) having two separate throughflow tube bundles (14,15) in a common surrounding shell, one said bundle (15) being connected to the outlet line (10) for liquefied petroleum gas for the evaporation thereof, and the other bundle (14) being connected to the outlet line (3) for boil-off for the overheating thereof, which tube bundles (14, 15) flow into a common mixing chamber (16) connected to the flowline (17).

3.

A system according to claim 2, c h a r a c t e r i z e d i

n that from the outlet line (10) for liquefied petroleum gas from the storage tank (1) there is provided a valve regulated line (20) to the common mixing chamber (16).

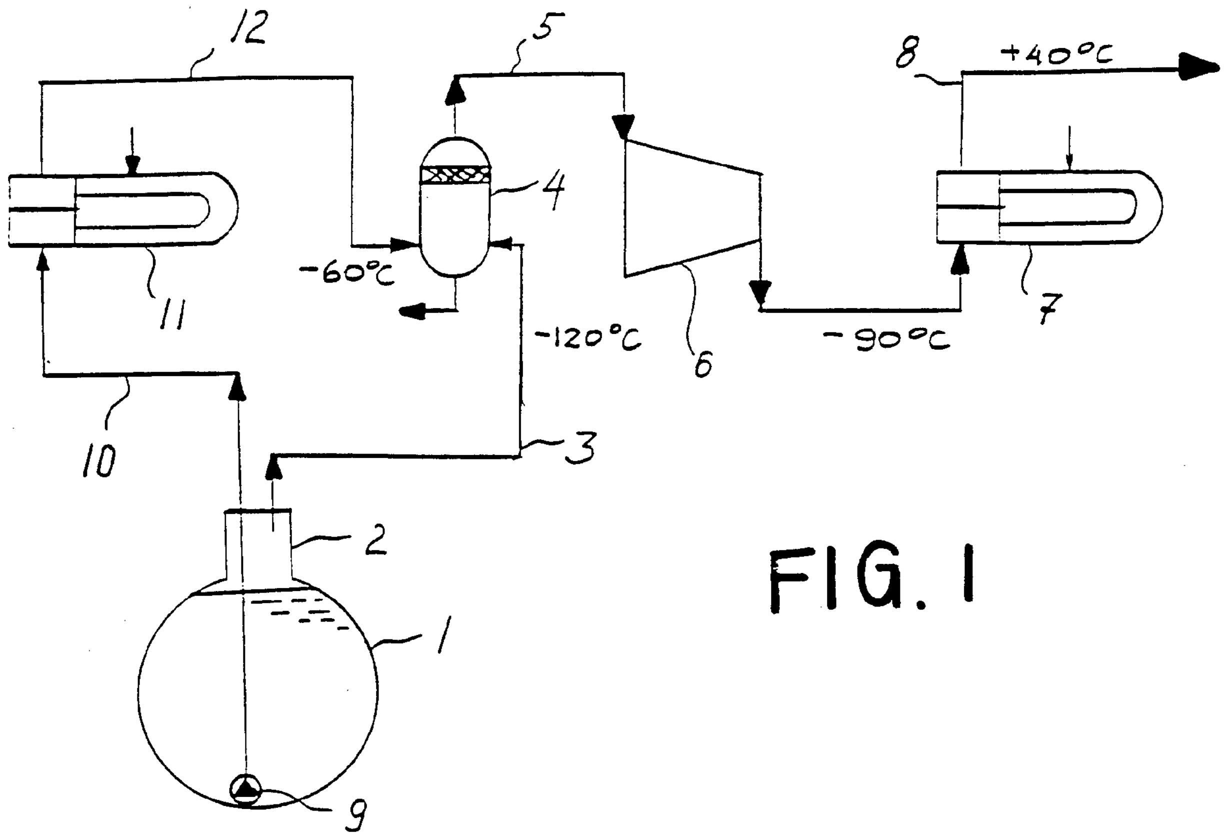
12
5
8
+40°C
4
-60°C
11
-120°C
6
-90°C
7
10
3
2
1
9

FIG. 1

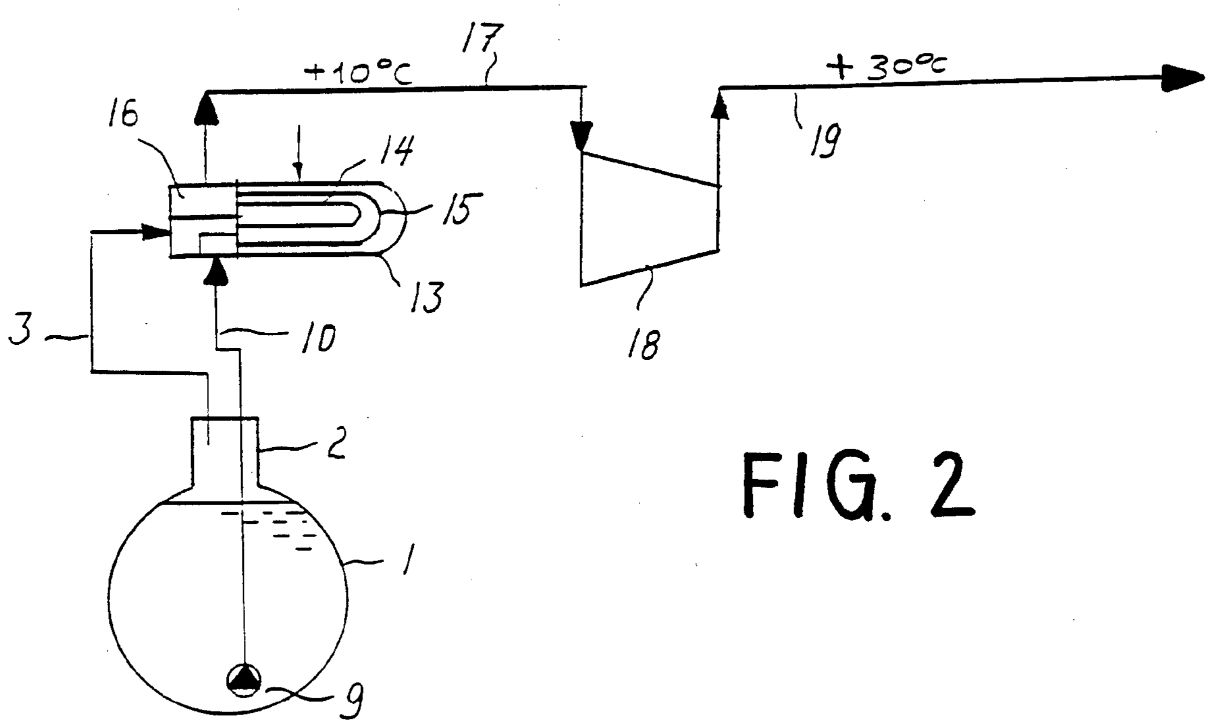
17
+10°C
+30°C
16
14
15
19
13
3
10
18
2
1
9

FIG. 2

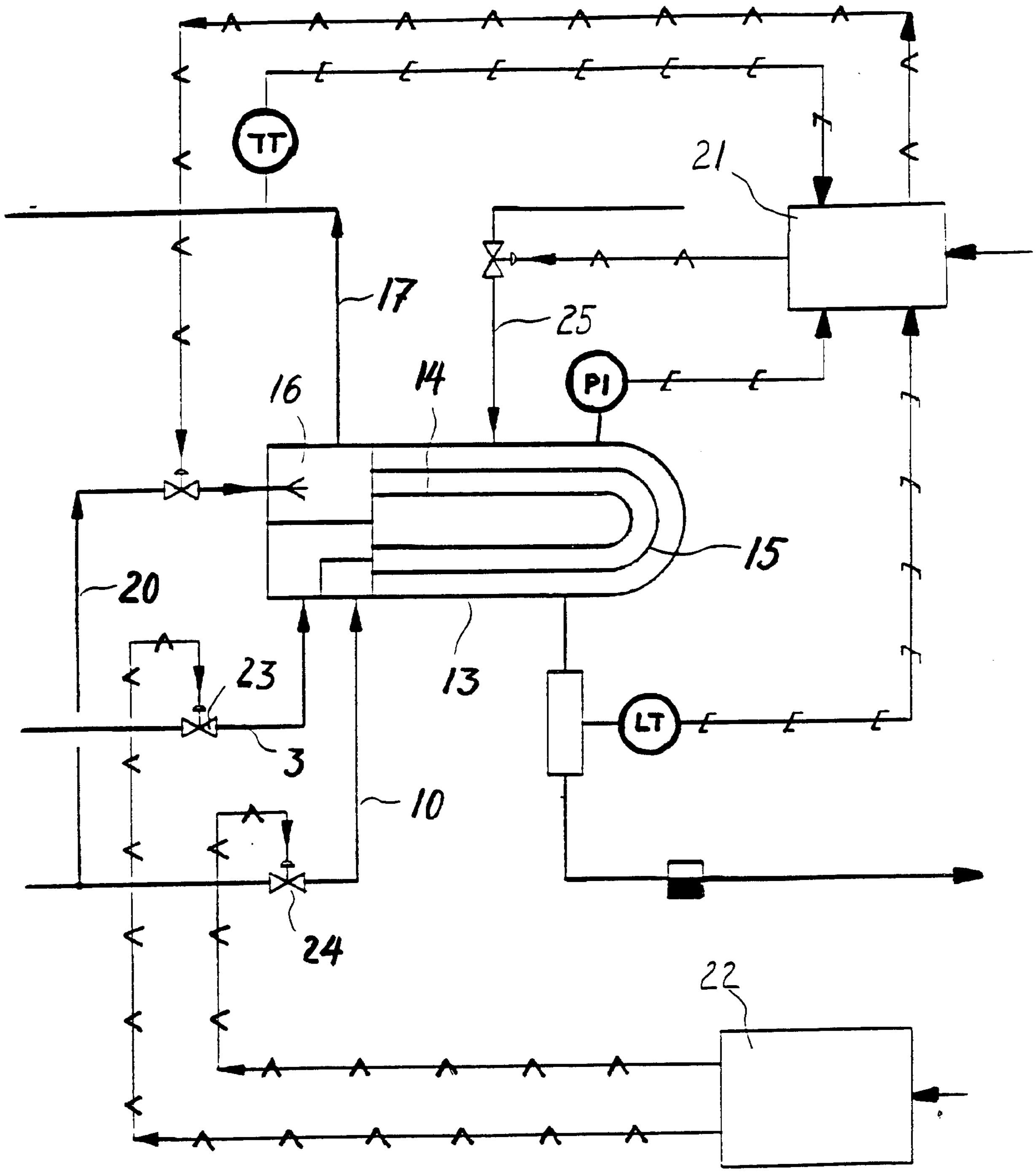

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 94/00020

A. CLASSIFICATION OF SUBJECT MATTER

IPC 5 : F17C 9/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 5 : F17C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP, A1, 0069717 (MOSS ROSENBERG VERFT A/S), 12 January 1983 (12.01.83), page 2, line 29 - page 3, line 26 --	
A	US, A, 2456890 (T.A. ST. CLAIR), 21 December 1948 (21.12.48), column 3, line 22 - line 64 --	
A	US, A, 2747374 (W.O. THOMPSON), 29 May 1956 (29.05.56), column 4, line 15 - line 38 -- --------	

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT
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26/02/94

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PCT/NO 94/00020

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP-A1-	0069717	12/01/83	SE-T3-	0069717	
			AU-A-	8557582	13/01/83
			JP-A-	58113536	06/07/83
US-A-	2456890	21/12/48	NONE		
US-A-	2747374	29/05/56	NONE		